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EVALUATION OF BULK DENSITY AND SOIL WATER DYNAMICS AFTER BIOCHAR APPLICATION

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Abstract

The aim of the present study is to trace the dynamics of soil moisture and bulk density in field experiment with adding carbonated plant residues (biochar) to the soil of broad bean.The experiment was carried out in 2018 on the experimental field of the University of Forestry - Sofia. The experiment was set with two meliorants - biochar (tree different levels) and manure (used as a background). Adding carbonated plant residues to the soil is a good solution for improving some soil properties, reducing fertilizer levels and increasing yields. Biochar has been extensively studied in terms of its impact on the water-physical properties of the soil, but only a small part of the results is obtained from field experiments.The soil dampness is crucial for cultivation of agricultural crops. The most accurate assessment of humidification conditions can be made on the content of productive moisture in the soil, because it is the moisture that plants actually use. Measurements carried out with a high-frequency moisture meter show that the dynamics of soil moisture is a closely related to irrigation regime and climatic conditions.

Key words: *soil moisture, biochar, physical properties.*

INTRODUCTION

Over the last decades, the humanity has witnessed various extreme weather events. The modern agriculture is facing intense rainfall, prolonged periods of drought and extreme temperatures during the winter and summer months.

In recent years, in the context of climate change, there is a great interest in studying biochar (BC) use in agriculture (Lehmann, 2007). The concept of biochar is increasingly falling under political and academic attention, and in several countries (e.g. the United Kingdom, New Zealand, the United States) "biochar exploration centers" have been set up.

Biochar is a porous, carbon rich material produced by heating organic matter to temperatures between 300°C and 1000°C in an environment with limited or no oxygen (Verheijen et al., 2010).

Biochar has been extensively studied in terms of its impact on the water-physical properties of the soil, but only a small part of the results is obtained from field experiments. The soil dampness is crucial for cultivation of agricultural crops. The most accurate assessment of humidification conditions can be made on the content of productive moisture in the soil, because it is the moisture that plants actually use.

The regularities of the formation of productive moisture in the soil and their quantification in different climatic areas and in different soil types and climatic zones most accurately determine the crop yield.

Adding BC results in a reduction in the bulk density, increasing the total pore volume, and increasing the water content in the root zone. Soil bulk density (BD) is one of the most important physical characteristics affecting water infiltration and water holding capacity (WHC). Biochar, being highly porous in nature (Downie et al., 2009; Lehmann & Joseph, 2009; Sohi et al., 2010; Verheijen et al., 2010) and having a high surface area can decrease soil BD after soil amendment (Oguntunde et al., 2008). Decrease in soil BD due to biochar amendment may enhance soil aeration and porosity thereby improving soil WHC (Haider G., 2016.). Tammeorg et al. (2014) found improved plant available water content in the topsoil (20 cm) and decreased soil BD during the first and second years, respectively, following biochar amendment. Jien and Wang (2013) found a significant decrease in soil BD from 1.4 to 1.1 Mg m^{-3}, saturated hydraulic conductivity and soil aggregation by using (*Leucaena leucocephala* (Lam.) de Wit) biochar at 0 and 5% in acidic Ultisol.

The assessment of soil humidity is important for studying water movement, crops water stress, evapotranspiration, irrigation schedule, etc. Methods used to determine soil moisture (gravimetric, tensiometricaly, electro-resistive, electrically absorptive, neutron, capacitive, TDR, lysimetric, etc.) require pre-installation time at the measuring site. With the exception of weighing lysimeters, they are point methods and do not give representative data for large areas.

The aim of the present study is to trace the dynamics of soil moisture and bulk density in field experience with broad beans.

MATERIALS AND METHODS

The experiment was carried out in 2018 on the experimental field of the University of Forestry - Sofia. The soil is fluvisol, slightly stony, slightly acidic. This area came under a continental climatic sub region, in a mountain climatic region.

To assess the effect of BC on soil moisture dynamics and bulk density, a field experiment with broad bean variety - Supre Gualdaluche originating in Italy was set up. The sowing was carried out on 05.04.2018, by scheme 60+50+50/25 cm.

The experiment was set with two meliorants - biochar and manure (used as a background). During the spring cultivation, the two meliorants were incorporated into the soil and were developed six variants: 1) control - no biochar and manure; 2) only with manure - 4 t/ha^{-1}; 3) biochar - 500 kg/ha^{-1}; 4) manure + reduced amount of biochar (250 kg/ha^{-1}); 5) manure + optimal amount of biochar; 6) manure + increased amount of biochar (750 kg/ha^{-1}). The experiment was carried out by randomized complete block design with four replications and protection zones.

Plants are irrigated by a drip irrigation system, the tape drip hose used has the following characteristics: I-Tape 8 mil/distance between drippers 20 cm/ 5.3 lh. The irrigation rate is 40 mm.

In determining the dynamics of soil moisture, a high frequency moisture meter DM400 (HIGH FREQUENCY MOISTURE METER) was used. For device calibration are taken parallel soil samples and was evaluated by weight thermostatic method in parallel. To determine the impact of BC on the soil water-physical properties as well as to further calibration precision, the soil density was determined to 40 cm depth in every 10 cm using the Kachynski method with cutting rings, with a volume of 100 cm^3.

RESULTS AND DISCUSSIONS

For the purpose of the experiment, information on climatic conditions and changes has been collected. An analysis of the meteorological conditions for the last 31 years was carried out in order to track the annual rainfall in the Sofia region (Figure 1).

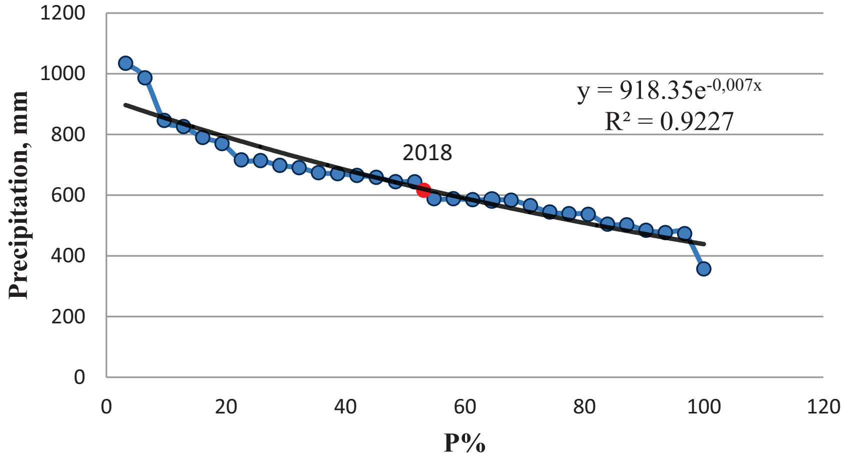

Figure 1. The precipitation provision curve for the period 1987-2018

Information on annual rainfall in the Sofia region is also collected. On the basis of this information curve of probability of precipitation per year has been prepared and according to the results obtained in 2018 it is characterized by secure close to 53%, which determines it as a mean dry year (Figure 2).

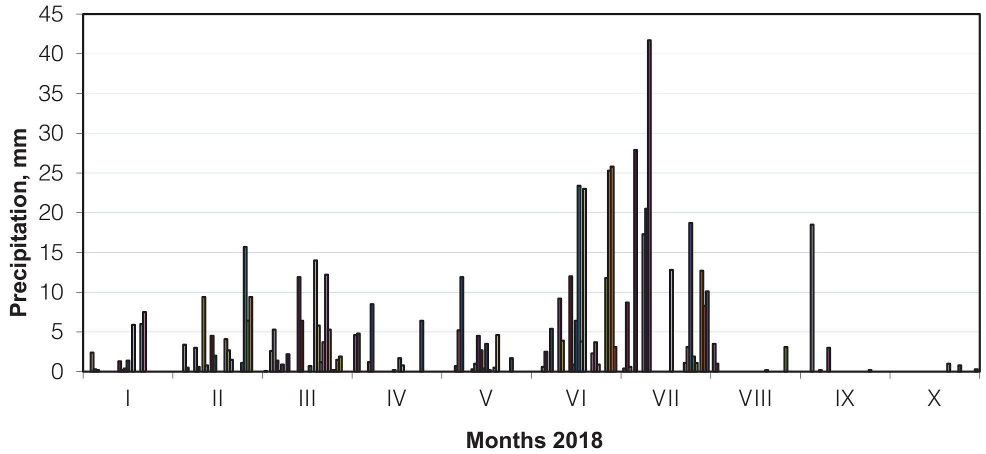

Figure 2. The precipitation for 2018, filed experiment - Vrajdebna

The reported precipitation from the beginning of vegetation period for faba bean (05.04.2018) is about 65.4 mm. In April, they range from 0.2 mm to 6.4 mm, mainly in the first two decades. These rainfall is insufficient to satisfy the culture's needs of water, which requires weekly irrigation. In May there is a uniform distribution, but the total rainfall for the month is 37.2 mm. The most intense rainfall was recorded on 07.05.2018 - 11.9 mm. Rainfall in April and May is below the average for a long time in the region of Sofia - V-54 mm and 72 mm for VI.

After the incorporation of soil ameliorants, in 2018, samples for evaluation of bulk density were taken from all variants, in the beginning of April The data are shown on Figure 3.

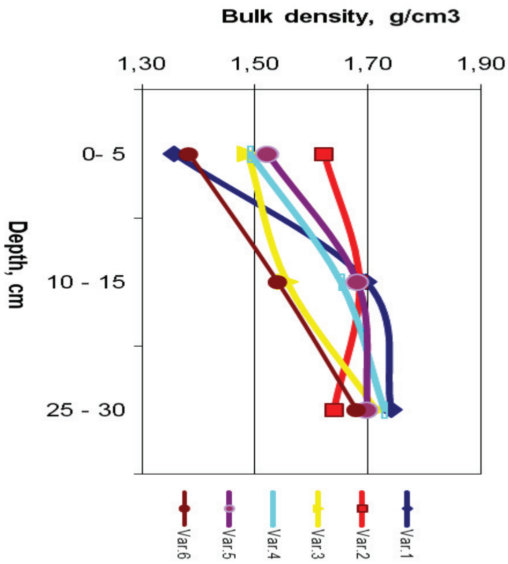

Figure 3. Bulk density of the soil - Vrajdebna, 2018

Data show that the introduction of BC and manure does not have the significant impact on bulk density. The bulk density increases in depth by moving from 1.36 to 1.74 g/cm^3. The lowest bulk density is in variant 6 with the highest content of BC.

This result probably due to the great amount of stones in soil, which that affect bulk density and humidity and cause greater variation. The compaction of surface layer is most likely due to irrigation. Similar data has also been obtained by Githinji L (2013) which concludes that with the increase of the imported BC the density volume decreases.

Application of BC improves the physical properties of the soil, but the results depend on the type (pyrolysis conditions and type of biomass) from the type of soil on which is applied and the rate of application.

Parallel to the direct soil sampling was measured with a high-frequency hygrometer, the data obtained are shown in Figure 4.

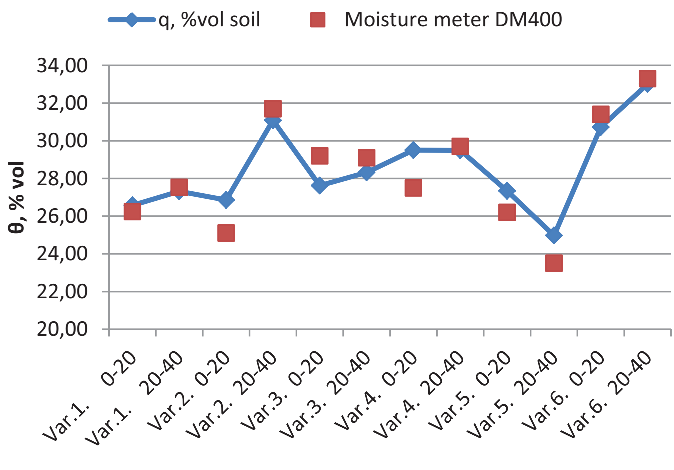

Figure 4. Data from soil moisture measured by two methods -2018

Because the device measures humidity by volume, it is necessary the result obtained by thermostatic method to be multiply by BD.
In the data processing and the conversion of the weight moisture to volume, the average density (1.61 g/cm^3) for the layer of 0-30 cm was used. It is clear from the graph that the measurements in the different variants in the two selected methods almost completely coincide. In some places, deviations of ± 0.5% are observed, which is within the standard error of the appliance specified by the manufacturer.
Based on the sampling, the dynamics of soil moisture (Wt%) in the main root zone is monitored. The data are reported by variants to track the influence of BC on the soil (Figures 5, 6, 7).

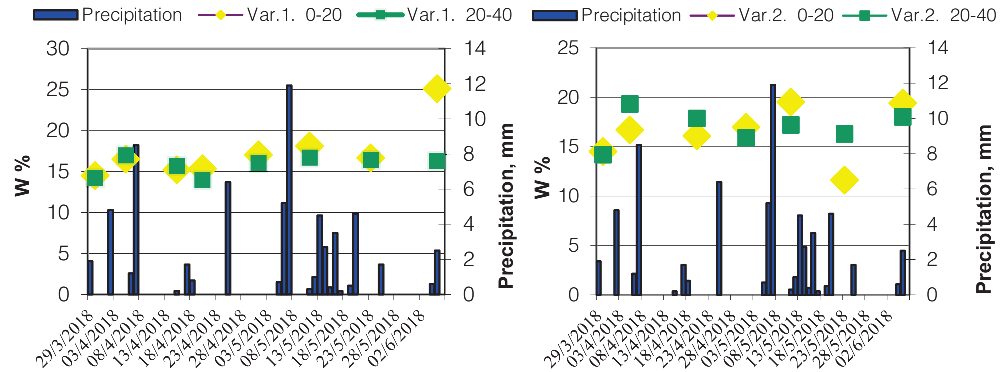

Figure 5. Dynamics of soil moisture in variants 1 and 2 - Vrtajdebna, 2018

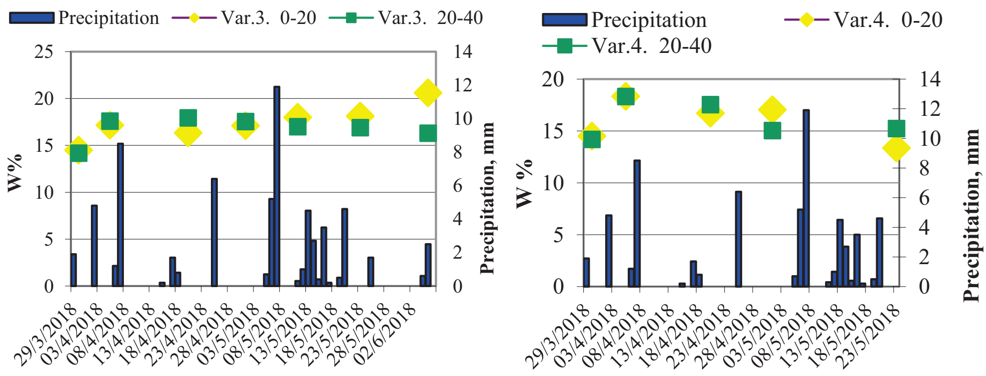

Figure 6. Dynamics of soil moisture in variants 3 and 4 - Vrtajdebna, 2018

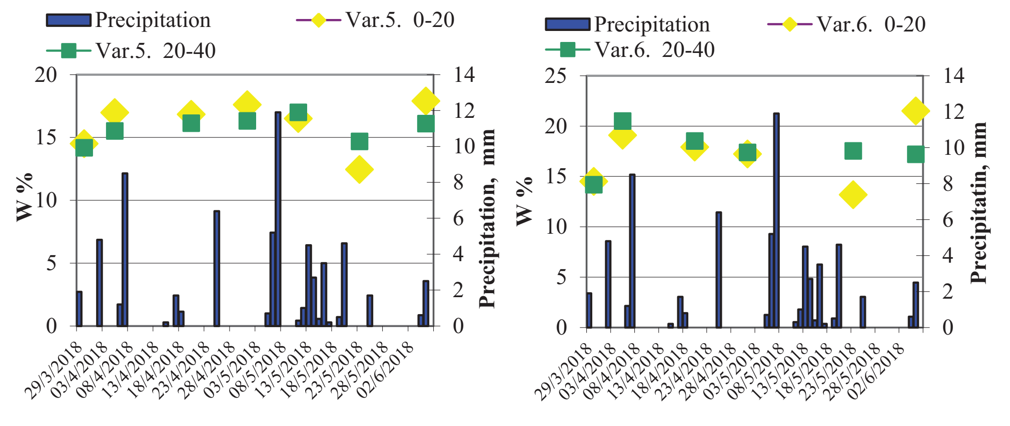

Figure 7. Dynamics of soil moisture in variants 5 and 6 - Vrtajdebna, 2018

At the beginning of the reporting period, moisture ranges between 16.5 and 20.5%, the lowest value being recorded in the control version of the two depths. Higher values of moisture are observed in depth, which has been shown for a good moisture load during the autumn-winter period. Highest values at both depths are reported for option 6 with an elevated rate of BC. This is due to the high porosity of the carbon, which increases the water holding capacity of the soil.

In early May, soil moisture ranges between 11.6% and 18.27%, with a decrease in moisture in the deep layer, due to the water derange in the underlying layers. Measured data at the beginning of June is one day after the irrigation, which also affects soil moisture regime. The moisture in the surface soil layer ranges between 16.1% and 25.1%. It has been noticed that the dynamics of soil humidity follow that of precipitation and applied irrigation. The available soil moisture in the soil is sufficient for the development of the faba bean, moving in the range close to the field capacity.

CONCLUSIONS

According to the obtained result biochar can be a good solution for improving some soil properties, reducing fertilizer levels and increasing yields.

The rainfall curves characterize the area of Vrajdebna-Sofia, as moderately humid and warm. Irregular distribution of rainfall required often irrigation of broad bean during the vegetation season. Accurate determination of the exact time of water application, as well as the correct calculation of the irrigation rate is of utmost importance. The need for a fast, accurate and non-destructive method required the use of the high frequency moisture meter. It was found that after accurate calibration for certain soil type, the method is accurate and fast.

The BD is determined by variant, the application of BG at the rate of 750 kg/da (var. 6) leads to a decrease in the soil density. In the other variants, no significant differences were found in compared to control variant.

It has been found that the dynamics of soil moisture follows that of the irrigation regime and climatic conditions. When saturation of soil with BC (var. 6) the highest and evenly distributed values are recorded. The available soil moisture in the soil is sufficient for the development of the broad bean, moving in the range close to the FC%.

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